Economic aspects of information and communication

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Economic Aspects of Information and Communication
Some Considerations

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1. Introduction

Although information can be considered a normal good just as any other good in an economic sense, some of its aspects make it worth devoting special attention to it. In this article we will try to point out these aspects, indicate their consequences for the economics of information, review concisely the state of the art in this field, and suggest directions for further research.

Much has been written about information but very seldom has information been defined in an operational sense. In fact, apparently quite different topics have been studied under the heading of information. For instance, the review article of Hirshleifer and Riley (1979) is only concerned with information as a means of reducing uncertainty. In the area of information technology on the other hand, information is just regarded as the transmission of signals (OECD, 1984). According to Naisbitt (1982), in his analysis of our information society, information is concerned with the production of knowledge. And, as a last example, we refer to the service sector which is sometimes also identified by means of the term 'information sector' (Giaoutzi and Nijkamp, 1988).

The common theme of these examples is that they are related to either data or information or knowledge, or a combination of those. These three concepts can be linked by means of the following definitions:

1) Information is the meaning assigned to data by known conventions (Samuelson et al., 1977).

2) Knowledge is the integration of processed information.

With processed information is meant that the (new) information is not just added to the stock of knowledge the receiver already has, but that it is interpreted, placed in a proper context, or understood. It can be compared to the refinement of ore into gold. Or, as an alternative example, if we consider the characters of a computer program as data, then reading such a program gives information about the program, how it may solve certain problems; however only when it is processed, compiled in this context, it really works and is able to actually solve problems.

Thus, data, information and knowledge form a sequel, in this order. Data however, can also be seen as *the symbolic representation of information*. The sequel is nonetheless not circular! To show this, the concept of communica-

tion is needed, which can be described as *the exchange of data.*

Now the previous elements can be represented as a series of successive events: information owned by economic agent A is transformed into a symbolic representation. These data are communicated tc another agent B who assigns a meaning to the data. Finally agent B processes and integrates the information with his stock of information to enlarge his knowledge. This series of events can be called the communication process.

Figure 1 shows the communication process excluding the final processing stage which is considered of no direct interest to the economist. The figure suggests that the same process may be described with different terms, depending on the perspective one has. We do not advocate here one exclusive perspective. In studying different aspects of the communication process the most appropriate viewpoint is adopted, including the related terminology.

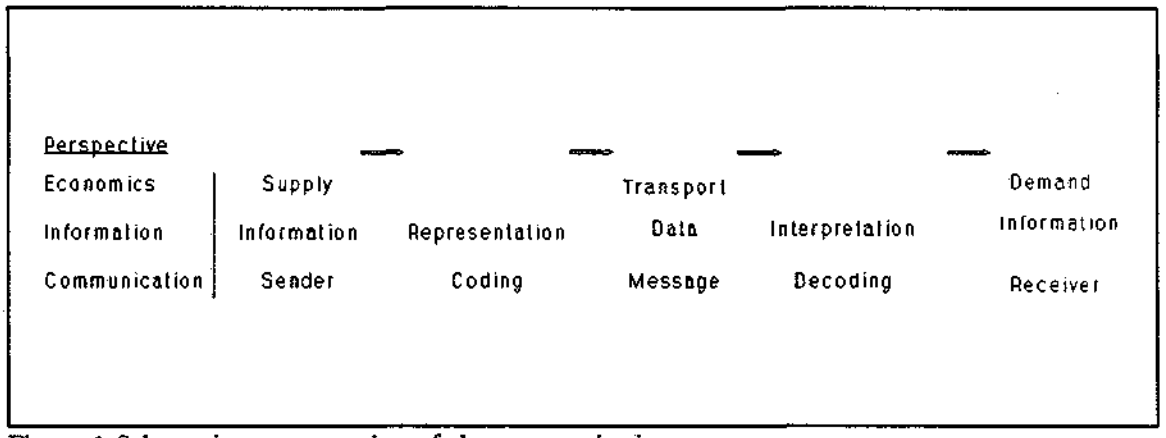

Figure 1 Schematic representation of the communication process

The entire communication process as shown in figure 1 will be the subject of this article. The communication process starts with the presence of some information possessed by an economic agent. Thus, at the start of the process we observe the owner of the information. In economic terms he is the producer (supplier) of the information, and can also be identified with the sender side of the communication process. At the end of the process is the consumer, who is also the receiver of the information. Producer and consumer are linked by a transportation line which will be called a medium in the information context. The transformation of information into data will be labelled coding; the opposite, the interpretation of the data by the receiver, decoding. A

package of data that is sent and received is called a message.

The non-circularity of the definitions concerning information follows from two reasons. The first is that the economic agents A and B are by definition not the same person. The second reason is that since the information is transformed into data and is then again interpreted to become information, this information is not necessarily identical at both ends of the process. This may be due to an inappropriate representation or interpretation, or specific circumstances in which the respective owners of certain information use it. For instance, when two persons have different insights in the current exchange rate of dollars, the information that something costs $ 2.- is still differently perceived by these two persons.

The above mentioned studies can now easily be related to parts of the communication process. Hirshleifer and Riley focus on the consumer side, studies like those of the OECD deal mainly with the media, while Naisbitt's study on the information sector is principally concerned with the supply side.

One property of knowledge which is important from an economic point of view needs to be stressed here. Information has to be represented or materialized to be transported. But once it has been materialized and transferred to the receiver, the sender usually still has the knowledge himself. Thus information has not gone astray, once it has been transmitted to others. This is an important difference compared to the transport of physical goods.

Such considerations on the communication process offer many interesting perspectives for a study on information. In the next section the description of the process and its consequences will be explored in more detail. In Section 3 the measurement of information is discussed. In Sections 4 to 6 three different uses of information at the reciever side are disussed, viz., information as an aid in decision making, information as a production factor and information as a consumption good, respectively. These uses more or less coincide with a usual classification of all goods: intermediate deliveries, investment, consumption. Next, Section 7 is devoted to the subject of medium choice and Section 8 concludes the article.

2 The Communication Process

In this section the communication process, i.e. the transfer of information

from a sender to a receiver, will be discussed and it will be indicated at which points of this process an economic analysis is meaningful. In the following sections some of these points and research already undertaken will be reviewed. It should be noted that in doing so a purely disaggregated approach is utilized.

The information process starts with the presence of some information on the side of some economic agent. This agent may be a firm, a consumer, 'the public sector', a scientist etc. The question of how this agent has acquired this information will not be addressed here (mainly because the answer will often be that he accumulated information in the course of years or got it from somebody else; then this was information in an earlier stage, which may lead to a vicious circle). It is assumed that information means a surplus value to the owner compared to the non-information case.

The owner of such information can act in different ways. Firstly, an agent can keep the information for himself and try to exploit it. For instance, a stock-market analyst who discovered some hidden facts about some firm may use this information to buy (or sell) the firm's shares. Secondly, the agent may act passively, e.g., when the stock-market analyst does not expect the price of the firm's shares to fluctuate enough to outweigh the transaction costs. Thirdly, the agent may try to sell his factual insight. The latter possibility may also relate to the scientist who tries to publish a paper in a journal: although financial revenues will usually be zero, there will be a return in the sense of personal satisfaction or increase in status. The attitude or reaction of the owner of the information may thus be the first point of study. It is also noteworthy that the passive reaction is not without any meaning in an economic sense. A consumer who is looking for some information may wish to know whether there are owners of the information not actively trying to sell it.

The next decision to make is to whom the information is to be sold. In many cases there will just be one potential buyer, but in other cases the owner can decide on his own whom to offer the information. In case the owner indeed has a free choice, it becomes very important to what extent and at which costs the information can be copied. For instance, if it can be easily copied and resold, it should be offered to all potential buyers at the same time. Such considerations may be a second point of study.

The third step to be made is the determination of the price the seller wants to receive for the information. This price will depend on many at-

tributes of the information, one of which are the acquisition or production costs. When the information is traded in a free market only the marginal costs will be important. Note that these marginal costs are often very low, or even zero. On the other hand, in some cases, for instance in the case of contract research, the total production costs will be the determining factor. Needless to say that the determination of the price is an important point of study for the economist.

The price the seller asks is not necessarily the same for all buyers of the information. This again depends on the possibility of copying the information: information is essentially non-depletable. The reason has a nice economic background, because selling the information means that the (potential) supply of the good has increased which ceteris paribus means a lower price.

Before the information can be transferred, it has to be coded. This is to a large extent a technical phase, but economics may again play a role here. One can imagine that in coding the information, a trade-off can be faced concerning the length of the message and the possibility of a correct interpretation of the message. Such questions can be analyzed with economic tools. The coding and decoding phases should then be handled simultaneously.

The next step in the communication process is the medium choice. It can be assumed that the data can be transferred via different media. The most well-known media are telephone, mail, telex, fax etc., but newspapers, periodicals, television, radio, folders, visits etc. can be added to this list. In principle, all information can be transmitted by all media, at least from a technical viewpoint. Actually this is not very surprising because all media use video or audio based data. The differences stem from the costs of the use of the media, including preparation costs, and these can indeed become prohibitive. But then again these costs are just one of the many attributes of the media and have to be traded off against other valuable attributes. Section 7 of this paper will be devoted to media choice, so that a further discussion may be postponed here. Only one point needs to be mentioned here. The choice of the medium will not in all cases be made just by the seller. It can also be made by the buyer or by both of them in a consultation process.

At the consumer side of the communication process, various aspects can be distinguished depending on the purpose of the information. Although 'the prime use of information is to provide a basis for decisions' (Samuelson et al. 1977, p. 47), other uses of information can be identified. One such a

possibility is that the information is merely consumed. Or the information may be used as an input in the production process. These different uses may be clarified with an example. Results of the economic division of a firm for instance, can be used for some investment decision. In the case of personnel following an educational programme, this programme can be seen as a production factor. People reading newspapers however, are just consuming information: they normally do not read the newspaper to take a decision, neither do they use the information in a production process. Each of these three ways in which information can be used at the receiver side will be analysed in more detail in Sections 4 to 6.

3. Measurement

A very difficult and intriguing side of information is its measurement. Actually two things can be measured: the amount and the value of information. There is not necessarily any relation at all between these two dimensions. At the same time however, the costs of transmitting data will relate to its amount, while the price one has to pay, or the revenue one wants for the information, will be related to the value.

The value of information is reflected in the price per unit of it. When the information is traded in a market, this price will be the result of the interaction between demand and supply. The way the supply price is determined is not very clear, however. Acquisition costs or production costs will play a role, but standard rules like price equals marginal costs do not necassarily apply, because the marginal production cost of an extra unit of the same, identical information good is zero (although there will be costs involved in the transmittance of an extra message). Also when the information is traded, the seller still has the information. So the only reason why he should <u>not</u> be willing to sell his information is that his trade-partner once having the information may cause a disutility or a loss to him.

At the demand side the picture is somewhat clearer. The value, which determines the price the buyer is willing to pay, depends on the attributes of the information he receives. In fact, it is not the information that is bought, but a message that has to be decoded before it can be evaluated. Thus it is the attributes of the message, in relation to the information the buyer is after, that determine the demand price. These attributes will be discussed

below.

The volume of the information, the number of data that is valuable for the receiver, is of course one of these attributes. As will be seen below, the volume of information can also be determined on another basis. But first a short review of the existing literature is presented.

In reviewing the literature it appears that the measurement of information has always been very context-specific. Theil (1966) uses a dimensionless unit to measure the informational content of messages, defined as the difference in entropy of the probability distribution of the states of the world before and after the message was received. In decision theory the value of information is calculated on basis of changes in expected utility (e.g., Hirshleifer and Riley, 1979), when an optimal decision is taken again on the basis of a distribution function of possible states of the world. Cravis (1981) uses another dimensionless unit, viz. Erlangs (defined as the average arrival rate of demands for telephone calls, divided by the reciprocal of the average length of a call), to make calculations on capacity problems of telephone networks. AT&T (1988) however uses number of telephone calls as a measure of the interaction between countries based on communication.

Concerning the volume of information a distinction has to be made between the various parts of the communication process. At the start and the end of this process we have -as described in section 1- information. However, in the transport phase we are dealing with data. It appears that during this transmission there always is a natural way of measuring the data, possibly depending on the context, as is inter alia reflected in the above mentioned Erlangs. Other measures may of course be used as well, e.g. time span of making telephone calls, bits in an electronic mail setting, lines for computer programs, words for an article, pages for a book, time for a TV-commercial spot etc. The common element in all these instances is a kind of volume which is appropriate as the basis for an economic analysis concerning the transmittance of information.

Clearly however, these measures of volume are in no way the determining factor for the amount or value of the information to the receiver. To him the various attributes or characteristics of the decoded message are important. Probably the most important attribute is the informational content of the

message. In a stochastic setting, where the information concerns probabilities of emerging states of the world, Theil's measure is appropriate. It is not very likely however, that all real world situations can be described as state-of-the-world problems. Reading some scientific article can be very informative without changing anyone's probability distribution function concerning states of the world. How then, should the informational content be measured?

Before trying to answer this question, it is useful to describe some other characteristics of messages in order to get at the heart of the meaning of informational content. These attributes of course also apply to the case of decision theory where informational content can be well described by Theil's entropy measure. Firstly, there is the concept of relevance. This attribute can be measured as the proportion of the volume of the message which is directly or indirectly related to the things the receiver intended to be informed about. Although this is difficult to measure in an unambiguous way, the meaning of the concept will be clear -and so its importance- to the receiver. Relevance can also be seen as a kind of efficiency measure: the higher the relevance, the more of the message will be used by the receiver.

A second attribute is the reliability of the message. This will to a large extent depend on the perceived reliability of the sender, but also on the performances in the coding, decoding and transmitting phases (cf. Marschak, 1974; Amershi, 1988). In decision theory, a measure of reliability can be elegantly developed. Normally the prior distribution and the distribution according to the message are multiplied and scaled so as to reach a proper posterior distribution:

$$P_{post}(x) = P_{pri}(x) * P_{mes}(x) / \text{scale}^{1} \qquad (1)$$

where $P_{pri}(x)$, $P_{post}(x)$ and $P_{mes}(x)$ refer to the prior distribution, the posterior distribution and the distribution according to the message received of the states of the world respectively. Scale is a constant defined in such a way that the integral of the posterior distribution function over all states of the world equals 1. Formula (1) is equivalent to geometrically averaging the prior and the message with equal weights. Now the relative reliability of the message can be accounted for by giving the message a

[1] We assume $P_{pri} \neq 0$

weight higher than 1 (the message is more trustworthy than the prior) or less than 1 (the opposite), given a weight of 1 to the prior. Or in the case that weights add up to 1, one arrives at a Cobb-Douglas type of formulation:

$$P_{post}(x) = P_{pri}(x)^{1-\tau} * P_{mes}(x)^{\tau} \; / \; \text{scale} \qquad (2)$$

with weight $0 \leq \tau \leq 1$, where $\tau = 0$ means an absolutely unreliable message, while $\tau = 1$ means evidence.

A third attribute mentioned here is the durability of the information of the message. This pertains to two situations. The first is the situation where no one else has the information, but one may almost be sure that somebody else will receive it some time. When this time span is short, quick action is needed to convert the relative advantage of having the information. This situation is well known in the world of journalism and may also be labelled as an exclusivity attribute. The other situation is when the information is only for some time relevant because of deterioration, outdating or a changing environment. Weather forecasts are well known examples in this respect.

Returning to the problem of determining the informational content of messages in a non-stochastic setting, recall that this informational content was assumed to be the dominant factor concerning the value of a message. It is clear however, that the value of a message will in part be determined by its relevance, reliability, exclusivity and durability too, but that these attributes are something else than the informational content of a message. Up till now the part of the message which was not new to the receiver, (i.e., "old news") was not excluded from the discussion. Exactly here we have a key to the concept of informational content of a message which may now be loosely defined as that part of the message which was not known to the receiver beforehand. Notice that this definition can, for instance, also apply to a situation of confirmation of a previously received message. The informational content of the confirmation then applies to the news that another person has the same opinion (insight). Clearly, the definition is still vague and hardly operational, but it may prove useful as an analytical tool for further analysis.

4. Information in Decision Making

Economic agents take numerous decisions every day. All these decisions taken together establish 'the market'. Analyzing this market, economists usually assume that decisions are taken under perfect information or -equivalently- in the absence of uncertainty (Varian, 1984). Stigler (1961) was one of the first to introduce uncertainty in an economic setting. He analyzed the situation of a consumer facing the possibility of producers charging different prices. Since then a vast body of literature concerning uncertainty and information has emerged, which was in the mean time reviewed by Hirshleifer and Riley (1979). In this section, the economics of information is restricted to the context of decision making, which is part of the whole field of information economics.

The economics of uncertainty is a natural and necessary preliminary to the economics of information. Whenever a decision maker has complete knowledge about all possibilities he is facing, he just has to evaluate his known utility function to take an optimal decision in a predefined sense. Complete knowledge means he is aware of literally all possible options he might face, that he has perfect insight into all consequences of all possibilities including those of the future, that he perfectly knows his utility function including his time preference rate and that he also is able to predict perfectly the future states of the world (these too may affect the consequences of his decision and his utility function).

It is obvious that such complete knowledge is impossible in real life, and in fact even in a meaningful economic analysis. Uncertainty prevails at all stages and parts of the decision process as described above. Economists have developed various ways of coping with uncertainty. For instance, concerning the uncertainty about the parameters of the utility functions, economists adopt the approach to introduce random disturbance terms. In other cases economists just assume the uncertainty away. Thus, it is often assumed that the decision maker is aware of all possible options concerning his decision. Though this may seem a natural assumption -decision making is choosing one of the available options-it is also a pragmatic one, not doing justice to real world situations. Similarly, perfect knowledge of the consequences of decisions is usually assumed, which again is a natural but not a realistic assumption. For instance, in making decions concerning joining a bet that re-

turns the stake, there is uncertainty about both the outcome, and the stake.

Uncertainty about the emerging state of the world, the outcome in case of the above bet, is most often dealt with. This uncertainty is most conveniently described by means of a probability distribution of the possible states of the world, that can be either discrete or continuous. Usually then, economics of uncertainty concentrates on the adaptation phase of the decision maker, in other words, according to his perceived distribution the decision maker tries to reach as good a 'position' as possible, given his initial endowment and prices. The position of the decision maker is then often expressed in terms of claims in emerging states of the world, which can be interpreted as sure returns in case a certain state emerges. Economics of information on the other hand concentrates on the possibilities to overcome uncertainty, or more appropriately: to reduce uncertainty. This may also be expressed as trying to find a more reliable distribution function.

Because the decision maker is still facing a distribution function after the receipt of information, it is clear that the economics of uncertainty is an essential part of the economics of information. In general terms, the economics of information considers three successive stages: trading in state-claims before anyone can get some information, the information acquisition stage and the trading of state-claims after some (private) or all (public) received the information. Many interesting results were derived in the seminal paper of Hirshleifer (1971).

Information acquisition is the same as the receipt plus the interpretation of a message in the terminology of section 1. The interpretation phase is often neglected in the literature (see also Marschak, 1971). This may be justified for the study of the decision maker, but should not be overlooked when the information system as a whole is studied[2].

A main and well known result from the literature is that a message or information that is received will never lead to a reduction in the (true) expected utility of the receiver (see Marschak, 1954). The reason is that if a decision maker would have made choice d_0 before he received the message with return r_0 and if his optimal choice afterwards would be d_1 with revenue r_1,

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[2] As an example an American producer considering whether or not to translate a manual in Dutch for the Dutch and Flemish market, should also consider the chances of correct use of his product in either case, resulting in satisfied customers.

this revenue r_1 is by definition not less than the revenue he could have expected, choosing d_0 with this expectation taken after the receipt of the message, i.e. using the posterior distribution. After receiving the message there is no point in comparing r_0 with r_1, because these revenues pertain to different situations. The expected gain of betting on horse A is of no interest to a person after he has heard that horse A will not run at all. But of course he will be glad to have heard this message because otherwise he might have made a bet on horse A.

Of course the decision maker does not know beforehand which message he buys, as otherwise he would not have to buy it. A more general model is therefore that the decision maker purchases an *information service* instead of a single message (see Marschak and Miyasawa, 1968). The information service is characterized by a set of possible messages one of which is actually sent to the decision maker. It is important to note that the set of possible messages is assumed known to the decision maker. The messages consist of distributions of states of the world. With some statistical tools it is possible to derive the possibility of receiving a message, given the prior beliefs of the decision maker. And because every message results in a non-negative return, it follows that every information service has a non-negative a priori expected value, that can be compared with the costs of purchasing it (see Hirshleifer and Riley, 1979).

In this concept of information services almost automatically a stage of perfect information was introduced, viz. the knowledge of the set of possible messages. This is similar to the assumed knowledge of all possible states of the world noted earlier, and the same remark applies here. But although this may be an unrealistic assumption in real life situations, in analyzing the decision making process, the emergence of disregarded options means essentially a badly defined problem.

The attributes introduced in the previous section to characterize messages are not very elaborately discussed in the literature about information and decision making. Marschak (1971) discusses the implications of introducing delays that may happen in information or communications systems. He observes that due to the presence of delays it may be preferable to buy less accurate, but more recent information. Delays become important in case information can become outdated or deteriorated.

Hirshleifer and Riley (1979) discuss the confidence of the decision maker

in his own prior distribution. This is of course counterparted by the attribute of reliability of the message. Their method of dealing with confidence is less satisfactory as they describe confidence as the tightness of the prior, by which they mean the variance of this distribution. This, however seems to be more related to the problem at stake than to the confidence of the decision maker. Consider for instance a random number generator. One can just believe that this generator draws numbers independently and according to the uniform distribution from the interval 0 to 1. But after a thourough analysis of 1000 drawings of such numbers one can come to the same conclusion. In either case the variance of the prior is the same, but certainly the confidence in the prior is much larger in the second instance. Therefore we prefer our treatment of the concept of reliability as proposed in section 3 (eq. (2)).

Marschak (1971) introduces the concept of informativeness of the previously introduced information service. Informativeness relates to the extent to which different messages of the information service differ from each other. In Marschak's model messages are said not to differ if they lead to the same choice (action) in the decision problem. The most informative information services are those for which each message assigns a probability of 1 to one of the options. Thus this informativeness is a measure of information services consisting of messages applying to the same decision problems and is therefore not comparable to what we meant above in our discussion of the informational content of a single message.

5. Information as a Production Factor

The classical production function in economics relates output to two inputs, labour and capital. Depending on the field of study, extensions are sometimes made including variables representing land, technological progress or energy in the specification of the production function. In this section we investigate the possibility to take account of information used in the production process.

Porat (1977) states that production is "(...) the transformation of matter and energy from one form to another. (...) Manipulation of matter and energy would be impossible without a sizable input of knowledge, planning, coordination, and control information" (p.2). Three quite distinct kinds of

information can be distinguished in the production process. The first is information resulting from the research and development activities of the firm. These activities are directed to the invention of new products or production processes. Machlup (1980) calls this socially new information as opposed to subjectively new information.[3] Socially new knowledge is knowledge which was not known by anyone else before and so strictly refers to inventions and discoveries. Research however, should be slightly wider interpreted,as this may also include activities related to copying existing, but patented products or processes. The second kind of information relates to administration and internal communication activities, such as planning and control. As a third kind of information present in a firm, we consider the educational level of personnel and the technological state of production capital. In this case we agree with Machlup that this is in fact knowledge, rather than information. However, the increase in these two variables is accomplished by buying information, perhaps incorporated in new machinery. We will discuss these three informational devices now in greater detail.

The organisation of a firm is very important. A good organisation results in short communication lines between management and production workers, leading to effective operating. Also an accurate administration leads to a good -and moreover timely- insight in the performance of the firm. Thus, investing in a good internal informational infrastructure may be profitable in various respects. This field of economics may be referred to as 'management information systems' (see e.g. Thierauf, 1987; Parker and Benson, 1988; Bemelmans, 1984). It should be noted that this kind of information production does not appear in usual statistical accounts of an economy, so that their relative importance for an economy cannot be assessed easily. Porat (1977), following Machlup (1962), developed a framework to estimate the share of informational activities in an economy and found for the US economy in 1967 that these amounted to 46% of the national product[4]. From

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[3]Machlup in fact makes a strict distinction between information and knowledge and should have used the word knowledge in this case. In his view the word information only has to do with the act of informing by means of messages; he considers the content of a message as knowledge. This differs from the definitions of these phenomena given in section 1. Also we are less concerned with a linguistically correct use of words as long as our statements can not be misinterpreted.

[4]It should be stressed that Porat considers all kinds of informational activity in this figure, including the manufacturing of computers etc. Nevertheless this result once more underlines the importance of information in

the same source it can be computed that 65% of its total demand was used as an intermediate input in the production process.

The stock of knowledge embodied in a firm is determined by the educational level of the labor force and the technology of the capital. The growth of both is accomplished by the acquisition of information. This statement will be quite clear for the case of education of personnel, but in general not for the technology embodied in capital. Yet buying machinery of a new 'technological vintage' can be traced back to the acquisition of some form of information, though it may be incorporated in the machine. This means that the technical growth rate, embodied or disembodied, may also be considered as an informational investment rate. Consequently, this rate depends on the investments of the firm in education and training and on the rate of investing in new capital, and thus it is in fact an endogenous variable. Rouwendal and Nijkamp (1989) have recently investigated the effects of endogenizing R&D on the performance of firms in a theoretical setting. Another example of a model in which the rate of technical process is (partly) endogenized is the vintage model of the capital stock of an economy (Solow, 1962).

Usually a distinction is made between labor augmenting and capital augmenting technical growth. In the above setting this is certainly a useful distinction. Moreover, it can be argued that both growth rates may not diverge too much. A typist who has to start working with a text processor may need some educational training. If not, the investment in the text processer may turn out to be counter-productive.

Again, the informational content of investments embodied in machinery cannot be easily determined, as we defined it implicitly as a surplus value of the investment in a new machine over an investment in a machine comparable to the old one. In this respect investments in education will be much clearer to assess and to evaluate.

Research and development activities aim at the same goal as the former kind of information, viz. technological progress in the sense of reaching higher productivity with the same capital and labor inputs. But there are some marked differences. First and foremost there is the risk of failure inherent in R&D: a certain line of research may appear to be a dead end, it may be impossible to develop an idea, or it may be too expensive to utilize it on an industrial scale. On the other hand, a successful innovation gives

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an economy.

a relative advantage over the competitors with all opportunities and risks involved. Of course, there are always risks involved, because there is uncertainty whether the consumers will like a new product, or whether factor prices will remain the same.

There is also a welfare dimension in the R&D activities. The argument that information can be bought in the form of investments in new machinery is dependent on a 'deus ex machina' kind of technological progress. That means, at least someone has to invest in R&D activities. It may even be assumed that the rate of technical progress an economy faces is by and large determined by the aggregate expenditures of the economy in R&D. Thus it may be profitable for an economy to favour private R&D investments by tax facilities or by (partial) protection of inventions. Some recent research endeavours on R&D impacts can be found in Davelaar (1989) and Goel (1990).

6. Information as a Consumption Good

Much information is transmitted and received without explicitly serving one of the goals of the former two sections. In those cases information is just consumed; referring to Porat's work once more, in 1967 35% of all information produced was consumed (Porat, 1977). Obviously all information received may influence decisions to be made in the near or distant future. For instance, though newspapers are generally considered as consumption goods, reading newspapers can influence the choice to enter the stock market some day. The key point in distinguishing this kind of decision making from that described in Section 4, is that the information is not sought by the receiver for a well defined decision problem. This description of consumption of information does not exclude the case of having a question answered or fulfilling one's curiosity. In these cases however, one is not solving a decision problem and therefore we say that the information is consumed. In this section the characteristics of information as a consumption good will be discussed.

In this discussion it is useful to stress the relationship between information and message once again (cf. Section 1). Conceptually the difference between these two is clear, in the context of production and consumption this distinction may become confusing. Does a publisher of newspapers sell either information or messages (newspapers)? His main concern will be the

number of newspapers he is selling, but the consumer is interested in the informational content of the newspaper. This discrepancy appears in many instances in the field of information production and consumption. Moreover, it is quite essential for an economic analysis, because the marginal value of the newspaper to the consumer is determined by the informational content, while the marginal cost to the producer is determined by the printing and distributing cost of the newspaper.

Another example concerns the case of telephone calls between households, i.e. two consumers. It may be assumed that both, or at least one of them, is informed during the call which is a benefit to him. This information however is usually free, the only thing being paid for is the use of the telecommunication service, and it is not clear beforehand whether the informed person or the informing person pays. Also the characteristics of the message (e.g. its length) determine the price of communicating instead of the characteristics of the information (such as its informational content).

Regarding the price of information it can be observed that much information is apparently offered free of charge. For instance, much information provided by the public sector is free. Also television and radio broadcasts are free, at least there is no direct link between subscription fees and the specific programmes one consumes. It may therefore be concluded that in such cases the sender of the information will benefit from the transmittance. But in that case there is no invisible hand on the market to regulate it to reach a social (Pareto) optimum, because consumers are usually not in a situation to play their role in this information game, as the supply side is dominating the information scene (e.g. witness the often unwanted delivery of advertising material to households).

7. Medium Choice

In order to transmit information communication means are needed. These include such media as telephone, mail, facsimile, periodicals etc. Most messages -the communicable form of information- can be sent by making use of many, if not all, of these media. However, in most cases only one of these media will actually be chosen. The present section is concerned with this medium choice problem.

Medium choice can be studied at two levels, the macro and the micro level.

First we consider the macro level. At this level attention is mainly directed to market shares and the influence of technological change on the relative attractiveness of the various media. Especially this latter subject has attracted a great deal of attention as a result of the rapid advances made in this field. However, it is not only the enlarged choice possibilities which are noteworthy to the economist. The introduction of computer technology in the field of telecommunication, telematics for short, has had a dramatic impact on the possibilities to disseminate information as such. It is illustrative that the first chapter of Naisbitt's famous study (Naisbitt, 1982) is devoted to the transformation of the industrial society to the information society. Also from a more serious viewpoint the subject has drawn much attention; for instance in 1982 the OECD organized a conference about 'changing market structures in telecommunications' (OECD, 1984). Finally, the impact of technological advance in telematics on regional development has been discussed in Giaoutzi and Nijkamp (1988).

At the micro level the medium choice problem may be studied in much the same way as the transportation choice problem: the structures of the problems are remarkably similar. In both cases the individual faces a discrete choice set out of which he has to choose one alternative. The alternatives can be described by their attributes which may be either discrete or continuous[5]. It is assumed that the choice is also influenced by the characteristics of the individual. Such models are classified as discrete choice models (see Amemiya, 1981; Maddala, 1983; Fischer *et al.*, 1990b). The transportation choice problem has been studied by many researchers, among others by Domencich and McFadden (1975) and Quandt and Baumol (1966). Fischer et al. (1990a) use a discrete choice model to study the medium choice problem in a universities contact context, viz. the logit model.

Moore and Jovanis (1988) integrated the medium choice problem in analyzing the interactions between telecommunication and transportation. In their very interesting paper they present a integrated framework for this interaction problem, of which the medium choice problem is a part. The medium choice problem is then discussed elaborately using a scheme which is given in Figure 2. This figure shows that the medium choice is determined by two factors: the characteristics of the message and the sender, and the (perceived) attributes of the medium. These two factors lead to a media prefe-

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[5] For a fundamental analysis of the characteristics model, which has inspired many researchers, see Lancaster (1971).

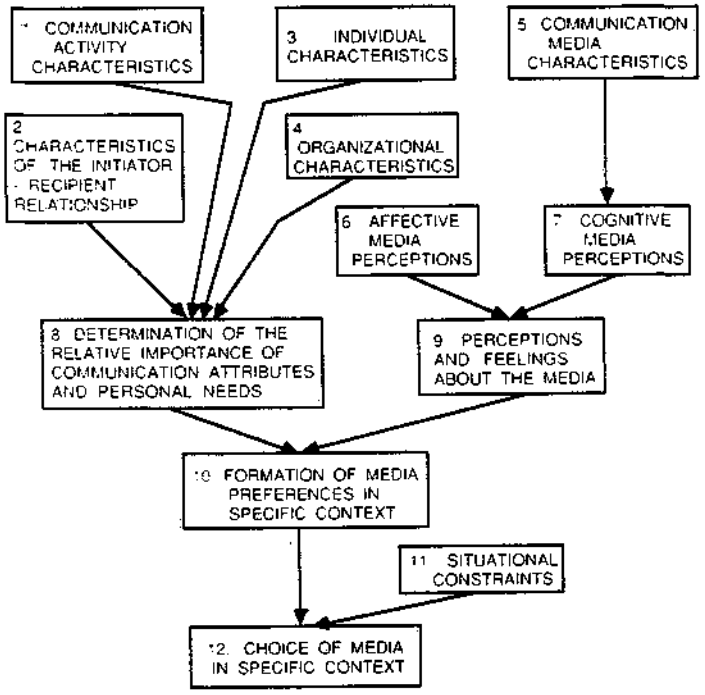

Fig. 2. Integrated framework for communication/transportation interactions: B. The media choice model.

Sorce: Moore and Jovanis (1988).

rence ordering which, confronted with situational constraints, leads to a medium choice.

Moore and Jovanis stress that the medium choice is very context specific, i.e. the choice does not only depend on the medium but also on the message. It is the requirements of the message to be transmitted, compared with the (perceived) characteristics of the various media that determine the medium choice. This may seem a quite obvious statement but it has a serious impact on the empirical part of medium choice research. It follows that it is very difficult to carry out a revealed preference kind of study, because not only the factual medium choice has to be reported on, but also the characteristics of the message, and the perceived characteristics of the media. Therefore a stated preference study is recommended (cf. Fischer et al., 1990a). It should be noted that this problem does not emerge in transportation choice analysis because in this field the choice problem is often quite homogeneous, e.g. when the home-work trip is studied. Stated preference methods have among others thouroughly been discussed in a special issue of the Journal of Transport Economics and Policy (1988). Cleraly stated prefe-

rence methods are a good means in the study of medium choice, provided they are carefully constructed. The design of stated preference experiments indeed needs much attention as can be concluded from a article by Fowkes and Wardman (1988) in the above mentioned special issue.

8. Concluding Remarks

Two interesting subjects have not been discussed because of the individual approach we adopted in the previous sections. We note them briefly here.

The first subject is information networks, like telephone networks. A number of questions arises in this field. How must the price be determined for the use of the network? Notice that the fixed costs of a network are quite large, but that the marginal costs are relatively small. Which conditions should apply for a link of the network to be deleted from or added to the network? Which capacity should be kept? Also welfare-theoretic considerations may apply to information networks. For instance, it is often argued that postal services as a public good should be offered to all citizens, but then questions may arise whether, for instance, this should also apply to telephone lines. And, as a last example, how should the total information stream be optimally organized?

The second observation is that information will sometimes just be a complement to other economic phenomena. For instance when one wishes to compare prices in different shops, this is not because of the virtue of the prices themselves but because one wants to buy a product as cheap as possible. In fact two of the three possible uses identified earlier, viz. information for decision making purposes and information as a production factor, establish a direct link between the communication process and other economic processes. In other cases however, (tele-)communication may appear to be a substitute to travel. Teleconferencing is an outstanding example in this field. Salomon (1986) has analyzed this substitution-complementarity problem of communication and travel in greater detail.

Information can be considered a normal good just as any other good in a economic sense. The main difference is that information is not physical. But when one starts considering the materialization of the information (which is a message), the difference tends to become less clear. Thus, from a theoretical viewpoint there is no evident reason to develop a new theory for the

market for messages (i.e. the field of (tele-)communications). Although there is no need for a special theoretical treatment of the communications market, this does of course not imply a neglect of the market in an economic sense, as it indeed is an interesting market as its economic meaning is rapidly growing and it is facing amazing technical progress.

Taking account of the peculiarities of information, the study of the subject can take many directions. Most widely discussed, also in this paper, is information in the field of decision theory. Other fields are R&D, education, communication medium choice, and estimation of the part of information activities of the total of economic activity. In our view however, the research issues discussed in this paper, do in most cases not take account of the peculiarities of information. In this respect much work remains to be done.

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